2 EQUIPMENT SUPPLIERS

2.0 EQUIPMENT SUPPLIERS

This section examines the vendors who supply semiconductor manufacturing equipment. There are approximately 534 of them. The top five are shown below in Figure 2.0.0-1. In 1989, these five companies held a 26.4% share of the semiconductor equipment market. The market share for the top five equipment suppliers was virtually unchanged over the 1988 figure, 26.3%. Japan-based firms hold four of the top five position in 1989, as compared to only three in 1988. These are: Tokyo Electron Ltd., Nikon, Advantest and Canon. The fifth firm in the top five is American-based Applied Materials. All, with the exception of Advantest, supply wafer fabrication equipment. Advantest is the leading supplier of automated test systems.

This section discusses how these and other competitors fit into the equipment market. It discusses their characteristics and how they successfully compete in the market. (Individual market assessments are provided in Vol. II, Vol. III and Vol. IV of this service.) The attributes and strategies that make them unique are examined.

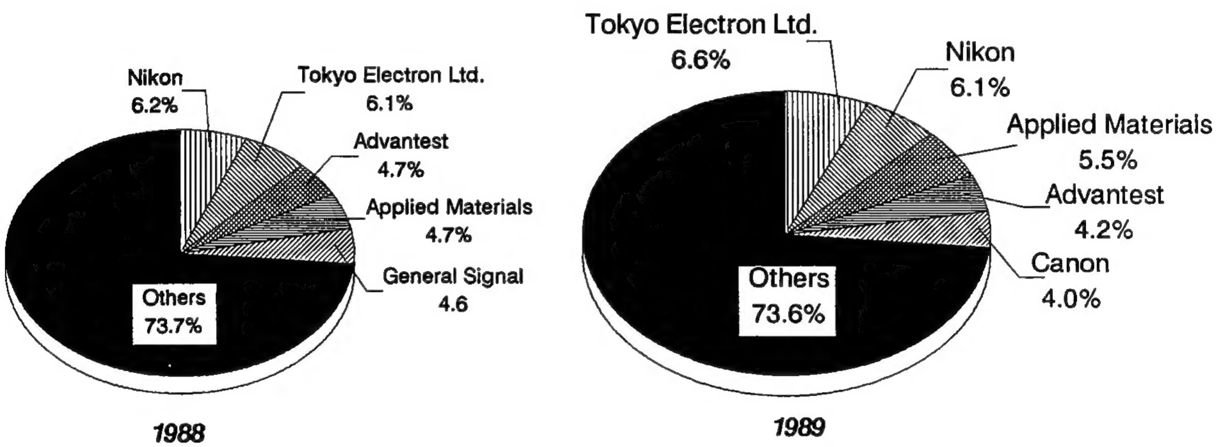

Figure 2.0.0-1

MARKET SHARE OF THE TOP FIVE EQUIPMENT SUPPLIERS (1989)

2.1 COMPETITIVE CHARACTERISTICS

2.1 Current Competitive Characteristics

There are approximately 534 firms that engage in the more than 149 markets for semiconductor equipment. These companies serve more than 500 semiconductor manufacturers and compete for a share of a nearly ten billion dollar semiconductor equipment market that is annually sold to a seventy-eight billion dollar semiconductor industry. Rapid growth and sharp business cycles (see Figure 2.1.0-1) have been the key drivers of a tumultuous competitive environment. This section characterizes the competitors and illustrates how they contend with the market characteristics.

Like the semiconductor industry, the equipment industry is international in scope: 64% are North American-based firms, 25% are Asian-based firms, and 11% are European-based firms. From another perspective, there are 226 companies competing in the \$3.1B questor systems industry while there are 184 companies in the \$5.6B wafer fab equipment industry. Assembly is the smallest segment with 124 firms fighting over a \$0.9B share of the industry. The composition of each market is displayed in Table 2.1.0-2.

Though the typical semiconductor equipment company has sales of less than \$15M, the top 50 semiconductor equipment suppliers have average sales of \$143M. The top 50 are listed in Table 2.1.0-3. They account for 75% of semiconductors equipment sales. In the previous year the top 50 suppliers held 74% of the total equipment market. The top 25 fab companies are listed in Table 2.1.0-4. The largest wafer fab equipment supplier is Tokyo Electron Ltd. It is followed by Nikon. Of the top 25 wafer fab equipment suppliers thirteen are North American-based firms, eleven are Asian-based firms and one is a European-based firms. The top 15 questor companies are in Table 2.1.0-5. The three largest questor systems suppliers offer automated test systems. KLA is the fourth largest supplier. It is the leading supplier of wafer and mask inspection systems. Assembly equipment leaders are shown in Table 2.1.0-6. Topping the list in 1989 is Shinkawa. Shinkawa and Kulicke & Soffa continually battle one another for the top ranking in this market. They both supply wirebonding equipment.

2.1.1 Development of the Industry

Since its founding four decades ago, semiconductor manufacturing equipment has been influential in shaping the direction and the pace of semiconductor manufacture. The equipment has been critical in determining the speed by which VLSI became production worthy and will remain critical through each new device generation.

The semiconductor equipment industry evolved out of the earliest semiconductor manufacturers. In its infancy, the semiconductor industry relied on modified equipment from other industries and on custom system designs that were contracted out to machine shops. The first semiconductor manufacturers kept captive equipment groups for this purpose. Eventually these captive equipment groups became a financial burden. There was no economic justification for parallel equipment development among many companies. Soon, a few pioneering companies recognized this and began to take on the responsibility.

Kulicke and Soffa was probably the first company to commence operations as a semiconductor equipment firm. K&S was founded as a partnership in 1951 and incorporated in 1956. Some of today's competitors were formed earlier, as Table 2.1.1-1 indicates, but at that time they were not

Figure 2.1.0-1

Worldwide Semiconductor Capital Equipment Market History
(in $M)

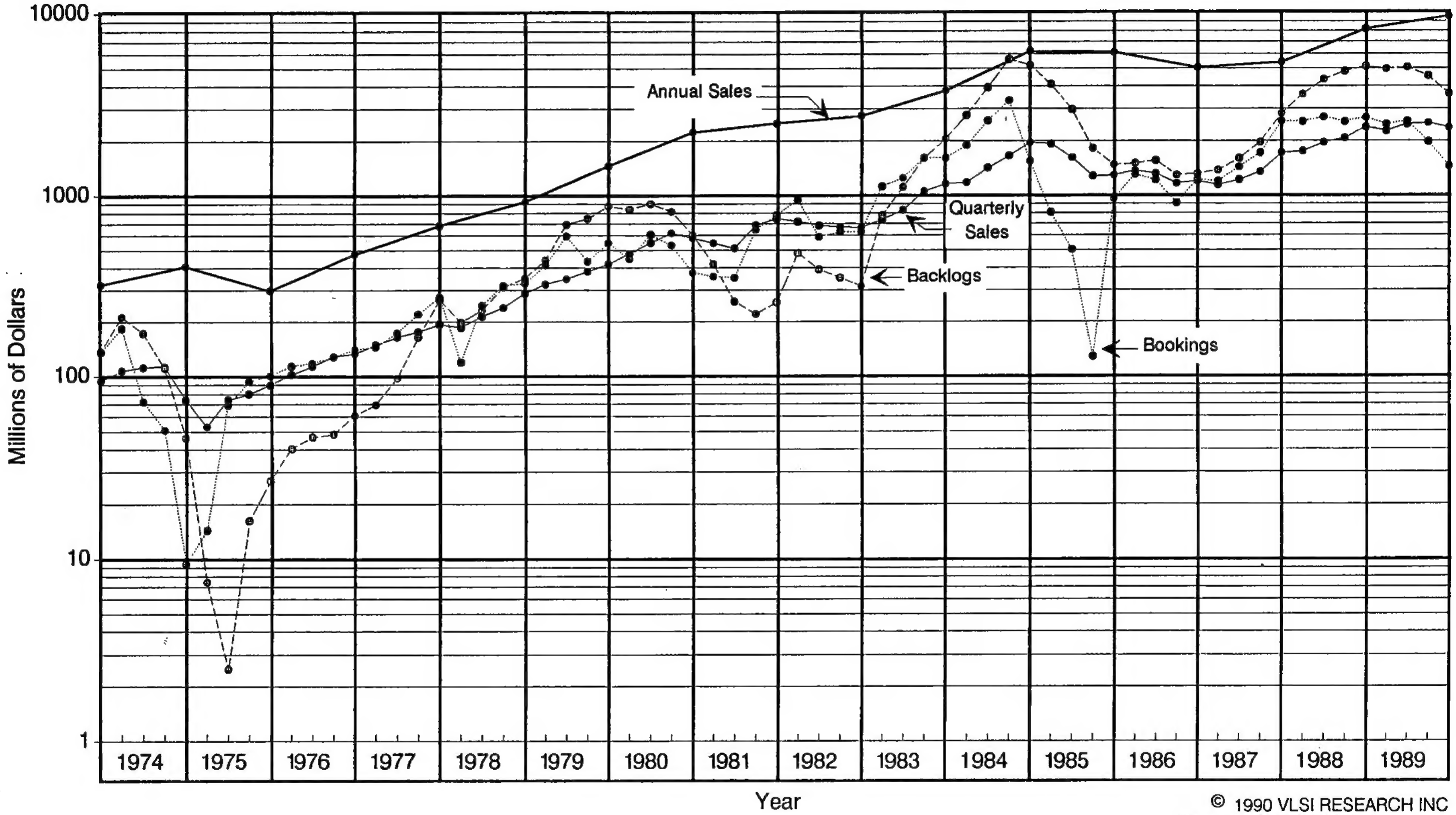

TABLE 2.1.0-2

1989 Competitive Market Composition

	Questor Systems	*Wafer Fab*	*Assembly*	*Total*
		Number of Companies		
North American	155	105	84	344
Asian	50	56	29	135
European	21	23	11	55
Total	226	184	124	534
		Worldwide Sales in $M		
Market Size	3121.3	5609.4	858.0	9588.7
Typical Sales per company	13.8	30.5	6.9	18.0

TABLE 2.1.0-3

THE WORLD'S TOP 50 SEMICONDUCTOR EQUIPMENT MANUFACTURERS
(1989 calendar year worldwide shipments in $M)

1989 Rank	1988 Rank	Company	Semiconductor Capital Equipment Revenues	Total Revenues
1	2	Tokyo Electron	633.9	1287.7
2	1	Nikon	582.2	1715.0
3	3	Applied Materials	523.3	523.3
4	5	Advantest	398.8	563.2
5	6	Canon	383.6	9497.9
6	4	General Signal	353.7	1918.3
7	7	Varian	335.0	1373.9
8	11	Hitachi	210.0	48679.5
9	10	Teradyne	199.9	483.6
10	13	ASM International	186.8	217.0
11	8	Perkin Elmer	166.4	792.8
12	12	Ando Electric	162.7	338.9
13	14	KLA Instruments	155.0	168.7
14	16	Silicon Valley Group	150.3	150.3
15	17	Dainippon Screen Manufacturing	148.5	983.7
16	18	Lam Research	140.9	140.9
17	23	Eaton	137.8	3671.0
18	26	ASM Lithography	129.2	-
19	15	Schlumberger	126.5	4686.0
20	9	LTX	121.6	121.6
21	24	Kokusai Electric	117.2	841.5
22	19	Shinkawa	107.6	107.6
23	21	Ulvac	107.4	-
24	20	Anelva	102.7	-
25	25	MRC	95.2	-
26	31	Genus	87.3	87.3
27	28	BTU International	81.4	101.2
28	22	Kulicke & Soffa	79.5	92.9
29	29	Hewlett-Packard	72.6	11555.2
30	27	Micro Component Technology	68.2	75.0
31	33	Tokyo Seimitsu	61.1	-
32	36	Tegal	57.1	57.1
33	30	Yamada	57.0	-
34	39	FSI	56.3	62.9
35	32	Towa Electric	55.3	-
36	53	Eaton/Sumitomo	52.9	-
37	60	Novellus	51.0	51.0
38	37	Electro Scietific Industries	50.0	84.2
39	34	Disco Abrasive Systems	49.3	-
40	47	Nissin Electric	48.9	580.8
41	35	Tektronix	48.4	1361.9
42	38	Megatest Corp.	48.2	48.2
43	41	Balzers AG	47.9	-
44	43	ET Electrotech	46.8	-
45	42	Asia Electronics	44.5	-
46	48	Sym-Tek	44.5	44.8
47	40	Cambride Instruments	44.2	-
48	44	Jeol Ltd.	42.3	-
49	46	Tencor Instruments	38.5	38.5
50	45	NEC Corp.	36.9	24508.1
		Subtotal	7146.5	
		Others	2442.2	
		TOTAL WORLDWIDE	9588.7	

TABLE 2.1.0-4

THE WORLD'S TOP 25 WAFER FAB EQUIPMENT MANUFACTURERS
(1989 calendar year worldwide shipments in $M)

1989 Rank	Company	Wafer Fab Equipment Revenues	Semiconductor Equipment Revenues	Total Revenues
1	Nikon	563.4	582.2	1715.0
2	Applied Materials	523.3	523.3	523.3
3	Tokyo Electron	508.6	633.9	1287.7
4	Canon	380.8	383.6	9497.9
5	Varian	335.0	335.0	1373.9
6	General Signal	244.1	353.7	1918.3
7	Perkin Elmer	165.3	166.4	792.8
8	Hitachi	152.6	210.0	48679.5
9	Silicon Valley Group	150.3	150.3	150.3
10	Dainippon Screen Manufacturing	143.3	148.5	983.7
11	Lam Research	140.9	140.9	140.9
12	Eaton	137.8	137.8	3671.0
13	ASM Lithography	129.2	129.2	-
14	ASM International	117.1	186.8	217.0
15	Kokusai Electric	112.7	117.2	841.5
16	Ulvac	107.4	107.4	-
17	Anelva	102.7	102.7	-
18	MRC	95.2	95.2	-
19	Genus	87.3	87.3	87.3
20	BTU International	64.1	81.4	101.2
21	Tegal	57.1	57.1	57.1
22	FSI	56.3	56.3	62.9
23	Eaton/Sumitomo	52.9	52.9	-
24	Novellus	51.0	51.0	51.0
25	Nissin Electric	48.9	48.9	580.8
	Subtotal	4527.4	4939.1	
	Others	1082.0	4649.6	
	TOTAL WORLDWIDE	5609.4	9588.7	

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TABLE 2.1.0-5

THE WORLD'S TOP 15 QUESTOR SYSTEMS MANUFACTURERS
(1989 calendar year worldwide shipments in $M)

1989 Rank	Company	Questor Systems Revenues	Semiconductor Equipment Revenues	Total Revenues
1	Advantest	398.8	398.8	563.2
2	Teradyne	199.9	199.9	483.6
3	Ando Electric	162.7	162.7	338.9
4	KLA Instruments	155.0	155.0	168.7
5	Schlumberger	126.5	126.5	4686.0
6	Tokyo Electron	125.3	633.9	1287.7
7	LTX	121.6	121.6	121.6
8	General Signal	91.8	353.7	1918.3
9	Hewlett-Packard	72.6	72.6	11555.2
10	Microcomponent Technology	64.5	68.2	75.0
11	Hitachi	57.4	210.0	48679.5
12	Tokyo Seimitsu	53.9	61.1	-
13	Electro Scientific Industries	48.9	50.0	84.2
14	Tektronix	48.4	48.4	1361.9
15	Megatest	48.2	48.2	48.2
	Subtotal	1775.5	2710.6	
	Others	1345.8	6878.1	
	TOTAL WORLDWIDE	3121.3	9588.7	

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TABLE 2.1.0-6

THE WORLD'S TOP 10 ASSEMBLY EQUIPMENT MANUFACTURERS
(1989 calendar year worldwide shipments in $M)

1989 Rank	*Company*	*Assembly Equipment Revenues*	*Semiconductor Equipment Revenues*	*Total Revenues*
1	Shinkawa	107.6	107.6	107.6
2	Kulicke & Soffa	78.7	79.5	92.9
3	ASM	66.9	186.8	217.0
4	Yamada	57.0	57.0	-
5	Towa Electric	55.3	55.3	-
6	Disco Abrasive Systems	47.0	49.3	-
7	Kaijyo Denki	25.2	27.2	-
8	ESEC	20.4	20.4	20.4
9	Lauffer & Butscher,GmbH	19.8	19.8	-
10	Kras	19.3	19.3	-
	Subtotal	497.2	622.2	
	Others	360.8	8966.5	
	TOTAL WORLDWIDE	858.0	9588.7	

engaged in semiconductor capital equipment. K&S used its mechanical expertise to develop the first commercial wire bonder for AT&T. The invention of the wire bonder made it possible to connect the semiconductor to the outside world.

Two important semiconductor developments occurred in the late fifties and early sixties that made semiconductors viable for commercial applications. The invention of the planar process and the integrated circuit allowed for reproducible mass manufacturing and for a steady increase in integration scale. These developments were also the impetus for the influx of semiconductor equipment manufacturers.

The planar process enabled the manufacture of relatively stable devices. With planar devices, internal circuit connections were much easier to make and reproduce. This increased yields which in turn opened the way for semiconductor devices to be used on new applications. Yields went up as volume increased which brought production costs down.

The invention of the integrated circuit combined with the planar process and scaling of linewidths allowed for a steady increase in capability. The result was a blossoming of new electronics applications made possible by ever increasing circuit complexity at decreasing prices. These two occurrences expanded semiconductor usage enough to create a viable semiconductor production equipment industry. Though, IC shipments in 1965 were only $29M, discrete semiconductor shipments had exceeded $500 million by then.

Soon, merchant equipment suppliers emerged. In most cases, these equipment firms

TABLE 2.1.1-1

SEMICONDUCTOR CAPITAL EQUIPMENT COMPANY HISTORY

PERIOD								
1935-1950	**1951-1955**	**1956-1960**	**1961-1965**	**1966-1970**	**1971-1975**	**1976-1980**	**1981-1985**	**1986-1990**
Perkin-Elmer (1938) Disco Abrasive Systems (1945) Veeco (1945) Advantest (1946) Balzers (1946) LFE (1946) Jade (1947) Varian (1948)	K&S (1951) Airco Temescal (1952) ASIA Electronics (1952) Ulvac (1952)	MRC (1957) Watkins-Johnson (1957) GCA (1958) Tylan (1959) Shinkawa (1959) Shinkawa (1960)	Technics (1961) Ultek (1961) Tempress (1961) Amaya Seisakusho (1962) Electroglas (1962) Sloan Technology (1962) Thermco (1962) ASM (1964) Accelerators (1964) Adar (1964) Branson IPC (1965) FTSC (1965) Solid State Eq. (1965) Oriel (1965) Anelva (1967)	PWS (1967) Lorlin (1967) Ultratech (1967) Applied Materials (1967) Kasper (1967) Mech-El (1968) ESEC (1968) Phoenix Materials (1968) Xynetics (1969) Adcotech (1969) Cobilt (1969) Macrodata (1969) Tesec (1969) Alma (1970) Align-Rite (1970) ADE (1970) Micronics Japan (1970)	Probe Rite (1971) Extrion (1971) Tegal (1971) Gasonics (1971) Dionex (1971) Microtest (1972) Accutest (1972) NBK (1972) Macronetics (1972) Adelco (1973) CVC (1973) Corso-Gray (1973) Silvatek (1975) Megatest (1975) Mosaid Systems (1975) Amedyne (1975) Sym-Tek Systems (1975)	ACS (1976) Eagle Test Sys. (1976) FET/Test (1976) LTX (1976) KLA Instruments (1976) Nanometrics (1976) Micro Automation (1976) AMI (1977) Trigon (1977) Pragmatic Designs (1978) Silicon Valley Corp. (1978) Centex (1979) AOT (1979) APT (1980) GenRad STI (1980) Lam Research (1980) IP Sharp (1980)	AG Associates (1981) Drytek (1981) Genus (1981) Ion Beam Tech. (1981) Basic Test Sys. (1982) Eagle Tech. (1982) Insystems (1982) Prometrix (1982) Attain (1983) Automated Electronic Tech. (1983) Axiom (1983) Cameo (1983) Plaser (1983) Tester (1983) Waterloo Scientific (1983) XMR (1983) Asix Systems (1984) FMS (1984) Focus Semi. (1984) Micrion (1984) Peak Systems (1984) SiScan (1984) Viewlogic (1984) XRL (1984) Adec (1985) Asyst (1985) Lasa Inds. (1985)	ICTS (1986) Knights Technology (1986) Nanosil (1986) Novellus (1986) Opal Inc. (1986) Advantage (1988)
1947 Invention of transistor at Bell Labs	1954 Texas Inst. announces 1st silicon transistor	1958 Invention of integrated circuit	1961 First commercially available integrated circuits	1967 First commercially available 64 bit ROM memory	1975 Worldwide semiconductor shipments exceed $5 billion	1979 Worldwide semiconductor shipments exceed $10 billion	1984 Japanese consume 50 percent of W. W. Silicon Production	1986 First commercially available 1M bit DRAM

were founded by equipment engineers from semiconductor houses. By the mid-sixties, these pioneers had managed to shift the main burden of equipment manufacture to themselves, returning valuable internal resources to the semiconductor industry. Both segments benefited, and the decade of the sixties became the golden age for semiconductor capital equipment start-ups.

Since then, the semiconductor equipment industry has been a fertile breeding ground for venture funded start-ups. The financial history of start-ups is shown in Table 2.1.1-2. The average start-up takes ten years to reach $40M in sales. It is typically profitable after three years. Otherwise it will be shut down after about seven years of effort. To date the most successful *fast start-up* has been Perkin-Elmer's ETEC group. In its first year it performed 18.5% better than the next highest firm. Meanwhile, LTX started out slow, but has had the best long term record for a venture funded start-up, despite its recent disappointing results.

Developments in semiconductor equipment have been essential in the development of semiconductor manufacturing since the late sixties. Table 2.1.1-3 lists critical equipment developments in semiconductor production. Plasma etching was probably the first equipment innovation to have a significant effect on the semiconductor market. It was placed in production in 1968 at Signetics. This was soon followed in 1971 by ion implantation which found its way from an R&D curiosity to become a manufacturing tool. In 1973, the first scanning projection aligner was shipped by Perkin-Elmer. These developments would soon be essential to the creation of LSI.

Branson IPC entered the market in 1965, by 1968 it had developed a commercial barrel plasma etcher. It was a technology developed by Gene Lemons and Steve Irving at Signetics. The plasma etcher soon received wide acceptance as it allowed for finer geometries in semiconductor manufacture.

In 1971, Lintott developed an ion implanter for semiconductor applications. Prior to this development, semiconductor makers had a difficult time controlling doping density. MOS ICs required precise doping which were impossible outside of the lab. Ion implant provided the means for precision doping. Eventually, doping accuracy obtained through ion implanters would lead to mass production of MOS ICs. MOS technology was essential to the development of VLSI devices. Unlike bipolar circuits, they required less power and did not require isolation for individual transistors. Thus more transistors could be integrated in a smaller area.

In 1973, Perkin-Elmer developed the scanning projection aligner. This was a major breakthrough and would soon replace contact aligners. The P-E aligner eliminated mask contact with the wafer and it eliminated shadowing effects from point source lighting. Wafers were no longer subject to the particulates and damage caused by contact with the mask. Lines could be placed more accurately with less CD variation because shadows were eliminated. All these factors in turn resulted in increased yield and reduced cost of manufacture.

In the early-seventies, Japan-based firms began entering the semiconductor equipment industry. Their entrance signaled the beginning of Japan's massive effort to challenge the United States for leadership in semiconductor manufacturing. Japan's semiconductor producers recognized the need to have a close and a ready supply of equipment. Thus the first Asian-based semiconductor equipment suppliers were financially as well as technically supported by Japan's largest semiconductor producers. Companies such as Advantest, Ando, Anelva, Canon, Nikon, Shinkawa, and Ulvac

TABLE 2.1.1-2

REVENUE HISTORIES OF VARIOUS EQUIPMENT STARTUP COMPANIES
(worldwide sales in $M)

Year Funded	Company	First Sales	Product	Years After Initial Funding 1	2	3	4	5	6	7	8	9	10
1977	LTX	1978	ATE	0.0	1.0	8.8	19.6	31.4	47.0	50.3	90.0	133.4	95.4
1976	KLA	1977	Mask Insp	0.0	0.8	3.3	7.2	13.1	16.2	21.6	39.1	58.3	77.6
1976	Etec/Perkin Elmer	1977	E-Beam	0.0	3.2	17.7	13.9	13.8	21.1	28.9	35.6	56.8	69.6
1977	Ultratech Stepper	1978	Stepper	0.0	0.5	2.0	2.2	17.2	27.0	68.2	37.1	28.1	62.1
1974	Tegal	1975	Etch	0.0	0.7	1.6	2.2	3.4	9.9	13.0	17.4	34.1	49.0
1975	Megatest	1976	ATE	0.0	0.2	1.5	6.1	8.5	9.3	11.8	17.3	23.5	35.2
1977	Silicon Valley Group	1978	Res. Proc.	0.0	2.0	2.5	5.1	7.2	13.7	17.0	30.4	36.8	27.8
1979	Gemini Research	1980	Epitaxy	0.0	2.7	3.2	5.1	10.2	18.8	21.0	19.9	16.0	25.1
1978	Consilium	1979	CIM	0.0	1.0	3.0	6.7	10.7	10.0	17.6	10.5	10.9	12.4
1977	Optimetrix/Eaton	1980	Stepper	0.0	0.0	7.2	9.6	22.6	19.1	32.2	22.4	2.4	0.0
1979	GenRad STI	1982	ATE	0.0	0.0	1.5	6.5	16.6	21.5	42.6	18.6	8.3	0.0
1980	Lam Research	1983	Etch	0.0	0.0	0.2	5.1	19.1	34.4	34.4	25.5	75.0	126.0
1978	Censor/Perkin Elmer	1979	Stepper	0.0	0.6	3.4	11.6	14.9	17.5	17.3	26.3	34.1	23.9
1978	OSI	1980	Wafer Insp	0.0	0.1	2.8	5.7	6.5	14.8	14.9	9.9	8.9	9.6
1982	Prometrix	1983	Inspection	0.0	1.3	6.6	6.6	6.0	10.5	12.8	14.3		
1983	Genus	1983	CVD	0.0	6.7	17.1	19.9	15.2	51.5	87.3			
1984	Novellus	1987	CVD	0.0	0.0	0.0	3.3	23.2	51.0				
1984	Ateq	1987	Laser Beam	0.0	0.0	0.0	4.0	13.7	18.0				
1982	Insystems	1986	Wafer Insp	0.0	0.1	2.0	10.6	18.0					
	Best 10 Year Results:		LTX	0.0	1.0	8.8	19.6	31.4	47.0	50.3	90.0	133.4	95.4
	Best Fast-Start Results:		ETEC/PE	0.0	3.2	17.7	13.9	13.8	21.1	28.9	35.6	56.8	69.6
	Best Slow-Start Results:		Lam Research	0.0	0.0	0.2	5.1	19.1	34.4	34.4	25.5	75.0	126.0
	Average Results:			0.0	1.4	4.4	7.9	14.3	22.3	30.7	27.6	37.6	43.8

TABLE 2.1.1-3

Major Innovations in VLSI Production Equipment

Innovations	*Year*	*Company*
Barrel Plasma Etchers	1968	Branson IPC formerly (International Plasma Corp.)
Electron-Beam Lithography Equipment	1969	Cambridge Instruments/JEOL
High Current Ion Implant Equipment	1971	Lintott
Scanning Projection Aligners	1973	Perkin-Elmer
Planar Plasma Etchers	1973	Texas Instruments
Automatic Wire Bonder	1973	Shinkawa
Plasma Enhanced CVD	1975	Applied Materials
Mask Inspection Equipment	1976	KLA
VLSI Test Equipment	1977	IBM
Wafer Stepping Equipment	1978	GCA
Silicide LPCVD	1981	Genus
Cluster Tools	1984	Drytek
Fully Auto Wafer Inspection	1985	KLA
Excimer Laser Stepper	1987	GCA
Multiprocessing Systems	1987	Varian
A VLSI Test Equipment	1987	Teradyne
Fine Pitch Wire Bonders	1988	Kulicke & Soffa
Scanning Wafer Stepper	1988	Perkin-Elmer

emerged in the seventies as a result. These companies had and continue to have close ties with major Japanese semiconductor houses.

Two of the first Japanese companies to offer wafer fab equipment were Canon and Kokusai. They offered contact aligners and epitaxial reactors, respectively. Japan's semiconductor firms were eager to buy from Asian-based suppliers. These companies quickly captured significant shares of Japan's semiconductor equipment market. In 1975, Japan-based firms held approximately 20% of their semiconductor equipment market. By 1980, they held 48.9% of Japan's semiconductor equipment market. Their worldwide market share had reached 18% in 1980 from an estimated 3% in 1975.

The first equipment produced by Japan's equipment vendors were 'American look--alikes'. There were reports of Japan-based trading firms reverse engineering American equipment and then introducing a similar equipment for the Japanese market. The first Japanese-built equipment was both similar in design and in function as those produced by American vendors. Nevertheless, in a short period of time, Japan's equipment vendors had begun tailoring equipment to Japanese semiconductor processes. These firms paid close attention to customer needs and were soon developing state-of-the-art production equipment for Japan's semiconductor requirements. By the mid-seventies, Japan-based vendors were producing some of the most advanced production equipment available to the world. Lasertec (formerly NJS) had developed an advanced mask inspection system. Disco Abrasive Systems developed an automated dicing saw, while Shinkawa developed the first automatic wire bonder. Together the automation developments made by Disco Abrasive Systems and Shinkawa made continued onshore assembly possible for Japan's semiconductor firms. These were also the first Japanese designed and manufactured systems to be competitive in the worldwide marketplace. This signaled the beginning of the Japan's equipment onslaught.

Other important developments in the late seventies were the invention of the VLSI test system and the wafer stepper. Together, these two systems would mark the beginning of full scale VLSI. Testing complexity and cost had become enormous with VLSI. Older types of test equipment could not economically test VLSI circuitry. The first VLSI test system was developed internally at IBM in 1977. This new generation tester featured scan-set testing to assure higher fault coverage of devices under test. This tester enabled higher reliability within chips. It also increased throughput, thereby helping to make VLSI logic devices economically viable. In 1978, GCA would introduce the first commercial wafer stepper. At the time, only a handful of individuals recognized that this new system would revolutionize semiconductor manufacturing. Wafer steppers increased yield significantly over that of projection aligners. Defects were reduced and steppers offered superior overlay alignment. Steppers used in conjunction with plasma etchers were proven to increase yield from 15% to 50% in a two micron 64K DRAM process as compared with conventional projection aligners.

In the early eighties, the first practical CVD reactor for silicide deposition was conceived and invented by Genus. The system offered the ability to deposit tungsten silicide via chemical vapor deposition. Silicides allowed the industry to overcome severe resistivity problems and allowed for multi-layer metal as the industry passed below two micron linewidths.

In 1982, Applied Materials introduced a revolutionary plasma etcher that effectively etched oxide films. Though predecessors

had claimed to etch oxides, AMT was the first to have a production worthy system with this capability. The key breakthrough was its high level of selectivity. It could etch 15:1 aspect ratios. This compares with earlier etchers that offered 3:1 aspect ratios. This development was critical for the production of devices with sub-three micron geometries.

In the mid-to-late eighties, several equipment developments occurred that would enable ULSI in a production environment. These inventions were commercialized by Drytek, GCA and Varian. The first systems carved out a window to the future of ULSI manufacture. In 1984, Drytek invented the basic system configuration needed for ULSI manufacture. Drytek (a unit of General Signal) introduced the Quad, a four chamber, single wafer processing system. It was the first cluster tool. It provided the architecture for multiprocessing systems that would later emerge in 1987. In late 1987, GCA showed its excimer laser stepper at Semicon/Japan 1987. The principle advantage of the excimer laser stepper is higher resolution over conventional optical steppers. It offers throughput rates similar to optical methods, but resolution similar to direct write methods. The excimer laser stepper has the potential to achieve 0.6 micron linewidths without sacrificing throughput.

At the same show, Varian displayed the first true multiprocessing system. The M-2000 was designed to combine several processes into the same system. It provided the contamination control necessary to achieve ULSI devices by combining RTP, CVD, PVD and resist processing, into one multiprocessing system. Systems such as these will be the key for high yielding 4Mb and 16Mb DRAM manufacturing lines. These systems gained enormous attention, but their complexity created mechanical handling problems as well as low uptime statistics. The success of these multiprocessing systems are critical to the volume manufacture of 16Mb DRAMs.

In late 1988, Perkin-Elmer introduced the long awaited step and scan lithography system, named the Micrascan I. It has been an 'open' industry secret for a number of years. The system has taken nearly six and one-half years to develop at a cost of more than $110M. The system stands to revolutionize the semiconductor industry. It offers the throughput of scanning aligners with the registration of today's best steppers. Pricing on the systems are estimated at $4.0M. It will be a number of years before these systems will be available to most semiconductor manufacturers. IBM, through its development work with P-E, has gained first right of refusal on the systems. IBM has essentially booked the first two years worth of systems.

2.1.2 Composition

The equipment purchasing environment changed dramatically in the drawn out recession of 1985 to 1987. Semiconductor companies were no longer content to buy equipment on the basis of performance alone. Other criteria such as perceptions among other users and financial stability became important factors in equipment selection. They started looking closely at the survivability of their vendors. SEMATECH was a direct response to their fears. Equipment prices and investment levels were skyrocketing. Today's semiconductor companies fear spending millions of dollars on equipment only to have their vendor exit the market. More than one company has told us, "We don't want to make another GenRad decision," referring to GenRad's ill-fated venture in VLSI test equipment, and GenRad is a fairly stable company. Consequently, they now pay closer attention

to an equipment company's structure than to raw performance alone.

There are three basic types of semiconductor equipment manufacturers serving the semiconductor industry. These are the independent merchant, the conglomerate merchant and the captive supplier. Though each produces equipment for semiconductor manufacturers, each have different motives, structures and customer relationships.

Independent merchants are those companies in which semiconductor manufacturing equipment is the mainstay of their business. Typical independent merchant firms include: SVG, PWS, Lam Research, Genus, Applied Materials, Kulicke & Soffa and Advantest. Most independent merchants are relatively small companies. Only Applied Materials has exceeded $400M in sales.

The market advantages and disadvantages of the independent merchants are directly related to their dedication to one industry. The highest levels of management in these companies are extremely focused on what it takes to be a success in the semiconductor industry. For example, they are more likely to recognize an impending change in business conditions and act accordingly. Fewer layers of management allow them to correct problems faster. They generally react faster with new strategies and product developments because upper management is fully committed to the industry. Their fast reactions often allow them to offset the greater resources of a conglomerate merchant. Customers will often prefer an independent merchant company for this very reason. They know they can get the President's attention if there is a problem.

The major disadvantage of the independent merchants is that they live and die by the cycles of the semiconductor industry. They are solely dependent on a highly cyclical market. They seldom have outside businesses to stabilize their revenue stream. Thus, most of the independent merchants structure themselves in such a way that they can survive during downturns. How they do this is discussed in Section 2.1.3 which covers Business Framework.

Most independent merchants have been funded with venture capital. Those firms that are venture funded can have a crippling disadvantage in today's market. The venture capital business has become extremely competitive in the last ten years. Consequently, venture capitalists are seldom able to wait for a market to develop. They look for orders to confirm solid interest from customers. Meanwhile, customers will intentionally delay orders to see if a company's venture backers really have staying power. This 'Catch 22' often leaves the vendor gasping for breath as customer and financier are at a stalemate. The primary goal of a venture fund is to take a company public. They make their money by selling to stock for as much as six to seven times sales through an IPO (Initial Public Offering). If a company fails to establish a healthy track record they will shutter the doors for fear of losing more investment funds. Teradyne's acquisition of Attain in 1988 brought to light an example of such problems. Attain had been a spin-off from LTX's West Coast operations. Attain's key engineering talent, Walid Baroudi had spent many years building test heads for LTX's 77 series linear testers. This experience gave him the inspiration to design the world's first analog per pin tester–the Attain Series 2000. Moreover, it was the first linear tester to come with a standard test head. As such, it was generally recognized as being the first and among the best of the new generation testers. The Attain Series 2000 was consistently winning shootouts at the most important customers. However, Attain was seldom able to transform these wins into hard copy orders. The continuing recession left them

fearful of an investor backout. Attain was shut down and sold for a fire sale price of less than one million dollars. It had two complete systems in inventory at the time it was sold to Teradyne. The two systems alone were valued at $1.0M. Moreover, Attain company officials have said that ten orders were pending and would have been booked had Attain received solid financial backing. Thus it is a vicious circle, the semiconductor industry will not support a company without financial stability and the company cannot get funding from VC's without orders from semiconductor manufacturers.

Conglomerate merchants are much more complex than are independent merchants. They differ from independent merchants in that they are a part of larger organizations. These companies often represent some of the world's largest corporations. Many have semiconductor equipment operations as one division of the company. Examples of conglomerate merchant companies are Nikon, Eaton, Perkin-Elmer, Varian, Schlumberger, Tokyo Electron Ltd. and General Signal.

The principle advantage of the conglomerate merchant is its size. It has the funding to buy its way into any market that it chooses to enter and to weather any business cycles that may occur. Customers recognize and often prefer this stability. The parent company's name generally commands instant recognition. It will also have the ability to transfer technical know-how between divisions. Key technical people can be transferred to other areas during business cycles. This allows them to retain trained employees for future expansions.

The major disadvantage of the conglomerate merchant is in its lack of ability to respond to a quickly changing market. Several levels of management are often involved in the decision making process. Decisions move slowly up and down the chain of command. Critical decision making has been known to take years in some companies. The commitment of key executives in this type of organization can vary widely. It is easy for dissident groups within the organization to hold up critical funding or approvals for any unit within the entire company. Moreover, the very fact that they have lots of resources allows them to be non-responsive, consequently, most conglomerate merchants are considered to be sleeping giants. Secondly, decisions that don't make financial sense in a small company seldom make sense in a large one. For example, when SEMATECH went to Perkin-Elmer to build the MEBES IV, they were quickly told that P-E would not develop the system for free. It simply did not make sense to invest $80M in a $40M market.

Another disadvantage is that customers often question a conglomerate merchant firm's commitment to the semiconductor industry. They know that semiconductor equipment represents a small portion of a conglomerate merchants total sales; that it can easily lose interest and leave them with unsupported equipment. Simple things like a change in leadership at the helm can dramatically alter a company's commitment. Another factor can be the tremendous difficulty of effectively managing different businesses and technologies. Many conglomerate merchants are diversified into aerospace, pharmaceutical, consumer and military markets. Sales to the semiconductor industry add a new dimension to their businesses. It is difficult for senior management to place enough attention on each segment. This can be delegated, but then several layers of management are created. Each needs to be convinced before new products are developed. Oftentimes, one executive can crush new product development simply by serving as an information barrier to higher levels of management.

Perkin-Elmer is an example of a conglomerate merchant that has chosen to exit the semiconductor equipment industry. Everyone in the industry was shocked when the announcement was made. P-E's announcement to divest its semiconductor equipment segment, has caused everyone to seriously look at the profitability and structure in the industry. P-E's decision to exit follows on the heels of its announcement of a revolutionary lithography system developed at a cost of more than $100M. P-E, a major conglomerate is concerned about the enormous cost of developing the next generation lithography tools. Few companies have the resources of a P-E, and P-E's move to exit clearly indicates the costs and risks are too high for the returns.

Management problems seem to be worst when a conglomerate merchant enters the semiconductor equipment industry by acquisition. The conglomerate merchant may lack the technical expertise to weed technically strong companies from weak companies. Even if it picks a technically strong company, it will often fail to create a healthy environment to maintain technical expertise. Key individuals credited for developing the start-up may be relegated to advisory management functions--or worse, they may leave the company. The company will usually lose its competitive edge as a result. This situation is typified by Eaton Corporation's rapid entry and slow demise in the equipment market. Eaton went on a highly publicized buying spree in the late-seventies and early-eighties. Their strategy was to become a general store for semiconductor makers. In a short period it acquired Kasper, Nova, Optimetrix, Pacific Reliability, Davis & Wilder and Macrodata. Today, the only successful part of Eaton is Nova. Eaton made all of these mistakes: It was slow to make decisions, it bought companies with aging technology, it chased off some of its best technical talent by trying to set uniform compensation levels throughout the company, and top management changes left the company with no champion for its equipment group.

In contrast, General Signal has been very successful in the equipment market by avoiding most of these mistakes. It tends to let acquired companies manage themselves. They are managed by setting long-term goals and GS mostly provides the resources to meet them. Though efficiencies are often lost through duplication of effort, GS has been able to maintain the key technical talent to bring new products to market. Nikon, and Varian have succeeded by being technically excellent at all levels of a company's management.

There has been no clear pattern of success among either independent merchants or conglomerate merchants. Table 2.1.2-1 shows who have made it into VLSI Research's Top Ten supplier listing and their shifts in position. Some independents have been very successful in the equipment industry. Advantest, Applied Materials and LTX are primary examples. There have also been successful conglomerate merchants such as Canon, General Signal, Nikon, Perkin-Elmer and Tokyo Electron Ltd.. Nevertheless, it is important to recognize that the displacement among the top supplier positions occurs rapidly.

Captive suppliers are the third type of equipment producer. They produce equipment for internal use only. Most of the world's largest captive producers have their roots in early semiconductor manufacture, when suitable equipment could not be purchased. Their captive groups were never spun off. Examples of captive suppliers are: IBM, TI, Philips, Hitachi, Toshiba, Siemens, National Semiconductor and NEC.

Captive suppliers produce equipment to maintain a competitive advantage in manufacturing. Advanced manufacturing equip-

TABLE 2.1.2-1

THE COMPANIES WHO HAVE APPEARED IN VLSI RESEARCH'S TOP 10 RANKING

(By Semiconductor Equipment Revenues)

Type	*Company*	*1979*	*1980*	*1981*	*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*
I	Advantest	15	10	8	9	10	11	8	2	4	5	4
I	Applied Materials	3	3	5	4	7	12	9	4	5	3	3
C	ASM International	21	18	14	13	12	16	15	12	12	13	10
C	Balzers AG	10	12	16	21	31	47	NA	30	28	41	43
C	Canon	18	14	10	7	11	10	NA	5	7	6	5
C	Eaton	8	7	7	5	5	4	6	16	16	23	17
I	GCA	4	2	2	11	3	5	10	11	17	*	NA
C	General Signal	-	8	9	8	6	2	3	3	3	4	6
C	Hitachi	-	32	39	NA	42	17	18	17	13	11	8
I	Kulicke & Soffa	9	9	13	13	14	15	NA	19	19	22	28
I	LTX	NA	NA	NA	NA	20	17	16	13	10	9	20
C	Nikon	-	-	52	10	8	7	14	7	1	1	2
C	Perkin-Elmer	2	1	1	1	1	1	1	1	2	8	11
C	Schlumberger Technologies	1	4	3	3	2	8	7	8	11	16	15
C	Tektronix	7	11	12	18	18	19	NA	24	25	35	41
I	Teradyne	5	6	6	6	4	6	5	11	8	10	9
C	Tokyo Electron Ltd.	26	15	11	12	9	3	2	4	6	2	1
C	Varian	6	5	4	2	4	9	5	10	9	7	7

I = Independent Merchant
C = Conglomerate Merchant

* GCA was purchased by General Signal in 1988. GCA's 1988 sales have been consolidated with General Signal.

ment is the critical determinant in a semiconductor company's ability to remain on the cutting edge of IC development. It allows a company to economically produce the most advanced IC's. One advantage to internal equipment production is that proprietary processes are kept confidential. This allows equipment design engineers to speak candidly with process engineers. This open communication allows captive equipment suppliers to tailor make equipment for them. Equipment can be optimized for specific applications when it is designed specifically for a company's internal usage. Process engineers run into fewer difficulties meeting required specifications once a product meets their requirements.

The primary disadvantage of captive equipment production is the drain on resources. It is costly to develop equipment. It is difficult to amortize the cost of development since a semiconductor supplier will typically only need a few systems. Key engineers must be dedicated to equipment design rather than IC production equipment. Once they have finished, there is little for them to do other than design new systems. Furthermore, captive suppliers soon find that they must support a marketing and sales department to convince internal engineers to use internally built equipment. Equipment brochures for captively produced equipment must be just as appealing as those made by merchant suppliers. Texas Instruments is famous for producing three color product brochures promoting TI-built semiconductor production gear.

Another costly expense for the captive supplier is related to documentation and support. Frequently, semiconductor companies do not make a real business unit out of captive equipment production. Equipment design is pursued on an ad hoc basis by one or two engineers who believe they can build a better system for lower cost. Proper documentation procedures are seldom adhered to in such cases. When the key engineers leave, the company is left with unsupportable equipment. Successful captive equipment suppliers have learned to function like a business with full support.

The difficulty of amortization of all of these costs can be changed if captives are willing to sell their equipment in the open market. Once merchant suppliers have caught up with captive equipment technology, there is no reason not to sell captively produced equipment on the open market. Texas Instruments has begun to use this strategy. It has contracted to have Megatest sell and support Texas Instrument's Impact LSI tester, while MRC markets the TI-built plasma etcher and microwave stripper. Most captive equipment suppliers in Asia pursue this strategy. They find that it is easier for them to recoup R&D investments in equipment development.

The customer base of Asian captive suppliers is usually comprised of their parent firm, American firms and some second tier Japanese firms. Japan's first-tier semiconductor firms are usually reluctant to purchase from a competitor's semiconductor equipment division. They do not want to allow a competitor's personnel into their fabs. This could lead to a dissipation of proprietary processes into the hands of its competitor.

Similarly, second-tier Asian firms are reluctant to purchase from Asian conglomerate merchants. They recognize that the equipment being offered is likely to be one to two generations behind that being used at the parent firm. Moreover, the process technology will not be provided. Thus the first tier firm already has an equipment advantage. If possible they prefer to buy their equipment from independent merchants. Second tier firms purchase from an

Asian conglomerate merchant only when there is no competitive equipment available from alternative sources.

2.1.3 Business Framework

The cyclical nature of the semiconductor equipment industry has a dramatic effect on its framework. Business cycles and product lifecycles are the most important business drivers. Its business cyclicity makes it difficult to maintain long term profitability. On average there is a downturn every three years. However, the eighties have been marked with five bad years out of ten. Consequently, equipment companies have had a difficult time making long term financial commitments. Short semiconductor product lifecycles require a heavy rate of product development. Each generation of equipment is obsolescent in three years and obsolete within five. This short product lifecycle makes it difficult to amortize the cost of the system's development.

Research and development expenditures have increased substantially over the years. A few hundred thousand dollars investment was sufficient in the seventies. Increasingly short product lifecycles and greater customer expectations[1] have created a heavy research and development burden on the industry's participants. One rule of thumb is that development costs will be roughly forty times the selling price of a new machine. By that measure, a stepping aligner will require over forty million dollars to develop. A new E-beam reticle writing system will require 96 million dollars. This creates strong financial pressures to postpone new products or to attempt getting by with cosmetic improvements. This is especially true during recessions. Nevertheless, firms who give in to these pressures usually lose out to more aggressive competitors. Those companies that fail to invest will eventually lose market share when competing against new systems.

These industry characteristics and the poor electronics environment of the eighties have made it difficult to fund future growth. The equipment industry has been marginally profitable since 1982. This is shown in Table 2.1.3-1. The greatest percentage of profit was realized in 1984, at a 12% pretax income. Yet, this profit was wiped out by losses in the following three years. Increases in research, development, and engineering costs (RD&E) have been the greatest culprits in this loss of profitability. The costs of RD&E have exploded in dollar terms as Figure 2.1.3-2 shows. Additionally, costs of sales, selling, and administrative costs have risen as a percent of sales. These additional costs have been the result increased customer support costs and the high cost of international marketing.

Successful equipment firms have taken measures to deal with the cyclicality, high rate of product development and funding problems in the semiconductor equipment market. The key factors to success are to smooth out swings and avoid a vertically integrated organizational structure. Successful firms have learned to work closely with semiconductor companies' during the critical formation period of new equipment technology. This ensures that new products will be successful and it allows a cost sharing during the product development phase. The most successful companies have built their businesses to have a low amount of fixed expenses, to maintain a low leverage ratio, and most importantly, to have lots of readily available cash. The balance sheet is

[1] This includes requirements for greater reliability, lower contamination, greater repeatability and greater uniformity.

TABLE 2.1.3-1

TYPICAL PROFIT AND LOSS STATEMENT FOR THE AMERICAN SEMICONDUCTOR CAPITAL EQUIPMENT INDUSTRY

(as a percentage of sales)

Item		*1982*	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Sales (%)		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Cost of Sales	(%)	60.5	55.6	55.0	59.8	61.0	62.2	52.8	55.7	56.4	57.4	59.2
Gross Profit	(%)	39.5	44.4	45.0	40.2	39.0	37.8	47.2	44.3	43.6	42.6	40.8
Expenses												
RD & E	(%)	13.4	13.2	16.0	17.3	16.6	17.1	14.0	15.0	15.0	14.2	15.1
Selling & Admin.	(%)	25.6	22.2	16.0	21.8	25.9	26.1	21.0	23.7	25.5	23.0	23.7
Interest	(%)	3.3	2.2	1.0	2.1	2.9	2.1	1.2	0.9	1.5	1.8	1.5
Total Expenses	(%)	42.3	37.6	33.0	41.2	45.4	45.3	36.2	39.6	42.1	39.0	40.3
Pretax Income	(%)	-2.8	6.8	12.0	-1.0	-6.4	-7.5	11.0	4.7	1.6	3.7	0.5
Av. Employment	(Persons)	81	71	102	88	74	79	111	120	116	136	141
Av. Productivity	($K/Person)	63.7	84.9	89.2	108.2	98.1	99.5	144.5	137.7	141.6	139.7	149.5

Source: VLSI RESEARCH INC

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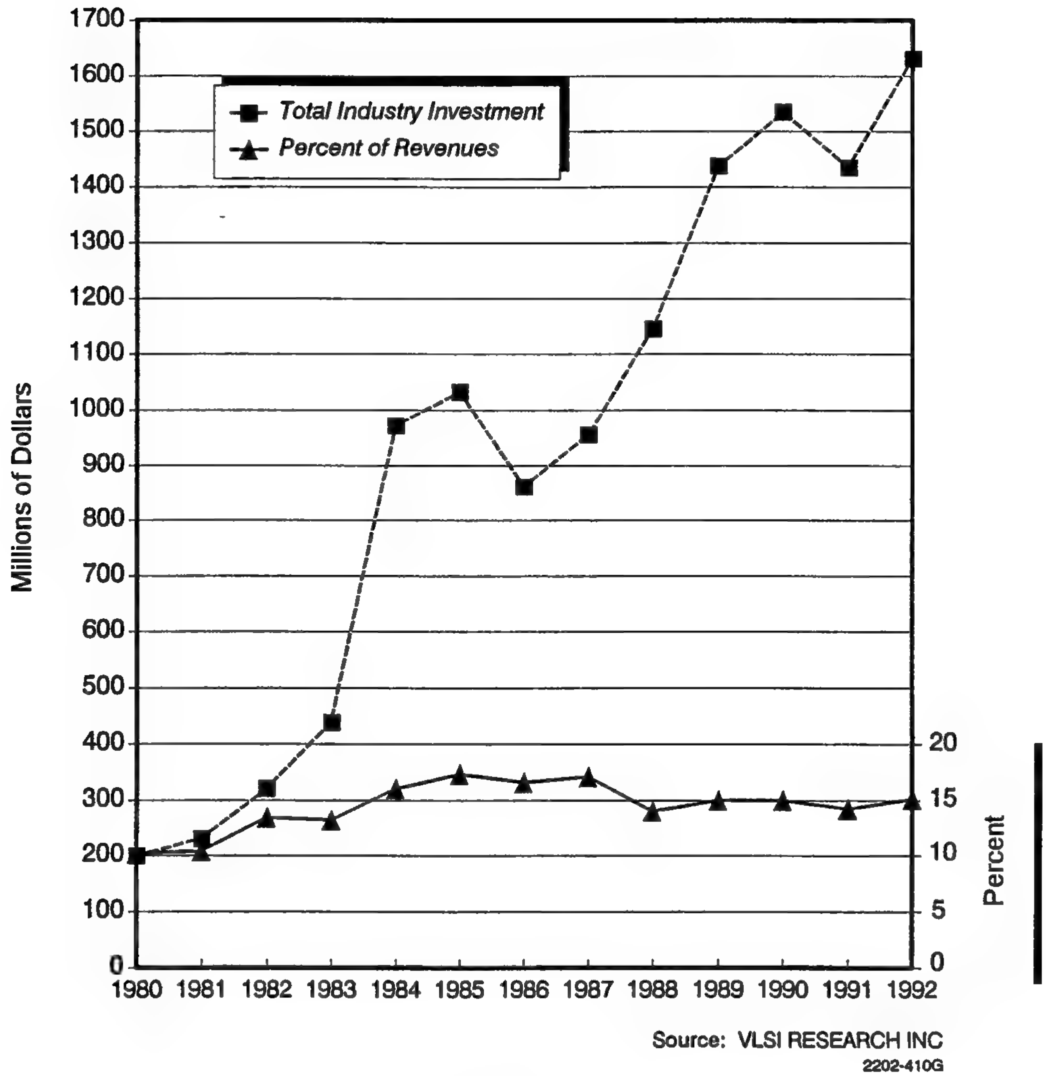

Figure 2.1.3-2

Semiconductor Equipment Industry RD&E Investments

one of the most important places to look when trying to ascertain the strength or weakness of an equipment company. Companies with weak balance sheets will not have the wherewithal to survive business swings. During an up-cycle, companies will make public offerings to generate cash. They will choose to reduce or even eliminate all long term debt. An equipment company does not want to contend with interest payments in a downturn.

Highly leveraged companies almost always have difficulties during downturns. They need cash to pay expenses as bookings plummet. No one wants to issue stock to obtain funds during a downturn, because this means selling the company at a bargain when stock prices are at a low. Moreover, long term investors would become disgruntled as their stake in the company becomes diluted. Additionally, the company cannot get additional loans. So it must cut people, overhead, and R&D. A leveraged company can soon find itself in quicksand.

The case of GCA Corporation is a good example. In the early eighties, GCA was the leading supplier of wafer steppers. In 1984, GCA recorded sales in excess of $300M. Earnings per share were $2.10. Its stock had sold for a peak value of $41 per share. However, its highly leveraged position made it a financial stack of cards. It held $96M in long term liabilities, while it had a mere three million dollar cash position. This amounted to only three days operating expenses. Meanwhile, it was pouring funds into expansion projects, while using lines of credit to pay everyday fixed expenses. When the industry crash of 1985-1987 occurred, GCA needed to issue stock in order to raise funds to pay its debts. During this period, GCA's stock dropped immediately to $4-$5 per share. Investors were outraged to see their ownership in the company dwindle and they sued. Several key management changes were made to try and correct the problems. This created a customer scare about GCA's stability and long term staying power. Many customers literally abandoned them and sales collapsed. GCA had several financial bailouts, as investors continued to watch their investment dwindle. Eventually, the stock price was worth only pennies. The final result: The company that had once dominated the stepper market was purchased by General Signal in 1988 for an estimated $76M.

Equipment companies have also adopted organizational structures that lends stability in the equipment market. Cutting fixed costs to a minimum and generating cash balances means that a company must getthe most out of its assets. Consequently, the most successful companies avoid vertical integration of their businesses. Equipment firms cannot afford costly overhead structures such as in-house machine shops. During slow periods, cash reserves are depleted by severance payments and other costs associated with maintaining under-utilized capacity. Worse, vertically integrated companies are slow to make needed cuts due to higher associated costs. The tendency is to continue building inventory in anticipation of an upturn. This strategy seldom works, because the inventoried equipment is usually obsolete when the upturn comes. It is often sold at bargain basement prices which further depletes demand. As an alternative to vertical integration, equipment firms have implemented manufacturing programs to use standard components. They have established good vendor relationships in order to maintain a readily-available high-quality supply of components. Equipment companies using this strategy must keep their vendors informed to their upcoming needs. An additional benefit to the equipment firm is its ability to reduce costs associated with reduced permanent personnel levels. Temporary or part-time personnel are used during busy periods. These measures allow a company to operate

at minimum cost during the slow periods, while allowing the capability for expansion during busy periods.

A good example of a company that successfully employed a vertical disintegration strategy is Varian's Extrion ion implantation division. In 1984, it was highly vertically integrated. The company's machine shop was building most of the components for its ion implanters. They were even winding power supplies. When the bottom fell out of the ion implant market that year, Varian found itself in the unenviable position of having heavy fixed overhead expenses. Varian soon recognized its plight and brought in a manufacturing expert from the aerospace industry (also a highly cyclical market), Mr. Robert Hozel. He immediately recognized the problems from being highly vertically integrated and restructured the company. This involved eliminating two-thirds of the division's employees as supporting functions were moved to outside vendors. By taking these measures, Mr. Hozel was able to ship more product in 1987 than in 1984 with only one-third the head count.

2.1.4 Competitive Environment

The semiconductor equipment industry is one of the most hotly contested markets to compete in. There are 534 companies fighting over ten billion dollar industry. Only 38 companies have semiconductor equipment sales exceeding $50M. Few companies can benefit from economies of scale since production volumes rarely exceed a few hundred systems over a product's lifetime. The typical company size is $18M. Compounding this situation is the fact that semiconductor producers wield enormous leverage over their suppliers. Semiconductor producers recognize that the semiconductor industry is the only market for the equipment offered by these vendors. Consequently, semiconductor firms tend to use this leverage to drive prices down. They reason that since the price per bit continues to decline, equipment pricing should also decline. But in actuality equipment prices have increased at an annual rate over the past ten years. Historical equipment pricing trends are shown on Table 2.1.4-1. Semiconductor producers have seen steadily rising equipment prices as a profitability problem for years. Thus, the advisarial relationship and pressure to continuously cut prices still exists.

2.1.5 Pricing

The large number of suppliers create the opportunity for buyers to play vendors off one another. There are often more than 20 companies competing for one sale. Typically, an equipment buyer will obtain a quote from one vendor; and then take the quote to another vendor to get a lower quote; they will then return to the first vendor for a new quote. The purchaser gives the ultimatum–if you want our business, beat these prices. A purchaser typically takes quotes from vendor to vendor until they get the equipment they want at the lowest price possible. The vendor that eventually wins the sale will make minimal profits or may even lose money on the deal. In a downturn, there are only a few semiconductor firms purchasing equipment at any one time. During these times, the equipment purchasers will have the most leverage. In an upturn, the tables will reverse. Equipment vendors will double or even triple prices as they come out with new technology.

Most vendors would prefer not to compete on price. Nevertheless, pricing frequently becomes the dominant issue since buyers have the advantage in negotiations. Ven-

TABLE 2.1.4-1

AVERAGE SELLING PRICES OF SELECTED SEMICONDUCTOR CAPITAL EQUIPMENT

(in thousands of dollars)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	82-92 CAGR
Wafer Exposure Equipment	523.2	563.0	549.3	535.7	645.7	642.6	915.7	1297.4	1200.9	1167.0	935.0	6.0%
Automatic Test Equipment	220.9	405.1	410.0	360.2	434.2	472.2	610.8	702.4	795.9	880.0	1100.0	17.4%
Assembly Equipment	32.0	47.2	59.9	62.5	68.5	74.5	85.7	91.9	109.8	113.0	120.0	14.1%

Source: VLSI RESEARCH INC
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dors recognize that they must often drop prices in order to protect their market share. Customers prefer to limit their purchases to one vendors equipment. This reduces their costs of training and maintaining spare parts. Consequently, it is essential for vendors to ensure that they get the first few systems into a customer's plant. Volume discounts are the most common type given. In good times, discounts of up to 10% are frequently given on multiple system purchases. In bad times discounts of 50% or more can be given. This may include a free one year service contract with spares. A buyer may also negotiate the purchase of multiple systems, and take immediate delivery of only one system. Delivery of follow-up systems may be spread over a period of several years. Table 2.1.5-1 shows the average selling price among three stepper vendors. Equipment pricing may fluctuate as much as 60% from year to year depending on market and competitive conditions. For example, 1984 was a hotly contested year. Consequently, steppers ASP's averaged $640K even though list prices were typically $850K.

There are many creative ways in which discounts can vary: Buy one system and get another free is a common form of discount among larger suppliers. For example, it is commonplace for stepper vendors to offer free resist processing systems. One vendor offered a free plasma etcher with each purchase of an ion implanter. Typically, companies will give away equipment that is hard to sell or that is even not selling at all. The pressure to get the first system at a customers site will often lead vendors to offer free trials. This offer includes free installation and use of equipment for a specified period of time at no charge. The strategy behind free trials is to 'buy an installed base.' The idea is to get the semiconductor firm hooked on the equipment, so that when the trial ends it will order multiple versions. Some customers have found that free equipment is a lucrative way to expand leading edge capacity in a downturn. One major United States' manufacturer is reported to have outfitted all its R&D needs with equipment on trial during the 1985 to 1987 downturn. Several major semiconductor manufacturers received entire fabs full of steppers on a three year trial basis. At the conclusion of the trial, the semiconductor producer could return the steppers at no charge, it could purchase the installed steppers at half price, or it could apply one-half value of the installed steppers toward the latest model offered by the vendor.

A variation of the free trial is giving customers free upgrades to an upcoming generation system if they buy the older generation system today. GenRad was the first company to do this with its GR16/18 model. LTX is well known for offering this option. Companies will use this type of discount to protect an installed base from competitors with new systems while it readies its own new generation system. The disadvantage with this method is that the returned system must be scrapped once the customer takes delivery of the new system. An alternative is to offer a free upgrade package. These upgrades will typically include software and hardware upgrades for some specified length of time. However, this can backfire on a company if the upgrades don't perform to the specs of a new system. Free one-year maintenance contracts are a common form of discount given to customers. Yearly maintenance contracts typically cost ten to thirteen percent of a system's purchase price.

Semiconductor producers have learned to capitalize on the cyclical nature of the industry and the various selling strategies. This is particularly true of captive semiconductor firms. Captives purchase during downturns when the discounts being offered are the most attractive, thus the cost of

TABLE 2.1.5-1

Historical Stepper Pricing
(in millions of dollars)

	1984	1985	1986	1987	1988	1989
Supplier A	0.60	0.63	0.93	0.98	0.95	1.04
Supplier B	0.70	0.82	0.61	0.70	0.92	1.15
Supplier C	0.62	0.44	0.76	0.68	1.00	1.21

capital is less expensive. They buy equipment and try to have it on-line just as the upturn occurs. Merchant semiconductor producers are almost always cash flow constrained during downturns and are not able to take advantage of any discounts. Consequently, they try to get free trial equipment. The roles reverse during sudden industry upturns or when new equipment is technologically advanced. In these brief instances the vendor has the upper hand. Premium pricing occurs. Vendors are able to command the full price for the system. Optional features, such as maintenance contracts, etc. must be paid for in full. Along the same lines, vendors will typically ask for a non-refundable downpayment at the time of order. There are also strong penalties for cancelling orders. Similarly, purchasers will often have to pay a premium or sign a contract for volume in order to receive early delivery. This is also the time when equipment prices will increase as new technology becomes available.

2.1.6 Entry Barriers To Capital Equipment Manufacturing

Barriers to entry are important competitive factors in the capital equipment industry. The major barriers have to do with technological limitations, cost, labor and maintenance. These will be discussed momentarily. However, it is also important to recognize what are not entry barriers to this industry. For example, the inability to reach some adequate economy-of-scale is not an entry barrier. The capital equipment industry is virtually immune from economy of scale limitations. This industry has no use for high volume manufacturing techniques. Most systems are highly customized to user's specifications. It is rare for any

equipment company to produce more than 100 units per month. Twelve per month is a typical industry average. Lifetime volume of a product seldom exceeds 600 units.

Likewise, the need for large distribution channels or numerous sales outlets is minimal. Often, three sales offices around the world will suffice. Key locations are Silicon Valley, Tokyo and Frankfurt or Munich. It has been discovered that a large number of sales outlets are not as important as being able to guarantee support. It is true that trade shows have become a major expense. The typical company will spend $200K per show. Larger companies may spend upwards of $500K. There are at least eight shows to attend: West, East, Southwest, Europe, Japan, Osaka, Korea, and China. The industry spends over $600M a year at these shows. Fortunately, shows are losing their importance as a sales tool. It is rare to receive a purchase order at a show. Most customers go through stringent and laborious tests. This usually includes several in-plant visits to the vendor. Consequently, companies are placing more emphasis on in-house demo facilities and less on shows.

The greatest barriers are technological. They include R&D management, technical selling, and system compatibility. These are barriers for those entering the equipment industry as well as for those already entrenched within the industry. These capabilities are essential to developing and selling a superior product.

Technological obsolescence is the greatest entry barrier to equipment companies. Capital equipment seldom wears out. But its practical operating lifetime is five years. It loses its state-of-the art status within three years. Equipment costing $1.0M typically requires $40M in R&D investment. Very few companies can afford these expenditures. The introduction of new equipment closely follows the increasing complexities of semiconductors. There have been four full generations of equipment designs introduced over the past decade. Each has followed the preceding generation by about five years. It is no coincidence that MSI, LSI, VLSI, and ULSI are closely associated with new generations of equipment. Due to high product turnover the equipment manufacturer must have the marketing personnel to assess customers' future needs. They must be extremely far-sighted and perceptive in order to conceive these new types of equipment. It often takes five years to develop equipment from conception to full-scale production. Consequently, while many equipment manufacturers are presently introducing new models, they are already in the planning stages for a new generation. Once future technology is identified these requirements must be relayed to R&D. For equipment starting in the characterization phase, the first prototypes will be delivered for evaluation in about two years. The first introductions will be made within three years. The first installations for full-scale production purposes will occur within four years. From the conception phase through to the introduction phase many opportunities for miscommunication arise. R&D engineers can make a technically superior product, but if it is difficult to use or doesn't meet customer needs, it won't sell. Managing these efforts requires great talent and mediation skills.

Technological selling is yet another barrier. It is difficult to obtain a sales force knowledgeable about the technology and the industry. Successful equipment salespersons are highly trained and know their field well. It is common to encounter salespersons with Ph.D.'s in extremely technical fields such as ion implantation and deposition. A successful company exists due to a successful sales force. Similarly, a salesperson with a bevy of key contacts and excellent sales skills can command a hefty salary among start-up firms.

Labor barriers to entry are commonplace. As mentioned above, the technology for building semiconductor capital equipment is limited by disciplinary skills. The loss of a single individual or a small group of individuals can sometimes spell disaster. Often a particular brand of equipment will succeed solely due to the reputation of its originator. If that person should leave, the equipment may lose its marketability. The ion implant industry is a prime example of this. There are a few key individuals who have been responsible for nearly all of the developments in the ion implant equipment industry. Companies would suffer greatly if these individuals were to leave their respective firms.

An equipment manufacturer must be willing to supply an adequate crew of well trained maintenance individuals in order to compete. Inability or unwillingness to maintain equipment is a serious limitation to both ongoing companies and to new firms. Capital equipment is the heart of the semiconductor manufacturer's pipeline. If it fails to work the manufacturer cannot produce. Semiconductor revenues are affected. If the equipment to be purchased lacks maintenance credibility, potential customers will not buy it, and existing customers will not make future investments with that supplier.

Strong maintenance credibility and worldwide sales support is a powerful sales tool against innovative new market entries. Semiconductor producers want to be able to get service personnel on site within twelve hours. However, the maintenance barrier will, more often than not, affect a new product from an existing firm to a greater degree than it will affect products from a new firm. What usually occurs is that an equipment supplier will stop manufacturing a particular product. It is subsequently removed from the list of equipment that the supplier is willing to maintain. The argument is often made that existing maintenance personnel are needed for the newer equipment. However, the semiconductor manufacturer will still need to keep the equipment operational. If that cannot be done, costly new equipment investments will need to be made. This creates bitter memories which can prevail for years. As the semiconductor industry has become worldwide in scope, equipment vendors have had to establish worldwide service and parts distribution. Users have become leery of those companies that cannot support equipment in some of the third world countries. They are cautious and tend to select vendors with proven staying power. One semiconductor equipment user said "I will not buy from a vendor unless I know that the vendor has survived two or three downturns".

New equipment suppliers have begun to establish alliances with other equipment firms in order to expand both their sales and service force. A typical example is the agreement between Bruce International and Ulvac. Ulvac, a Japan-based firm manufactures a tungsten CVD system, while Bruce International markets and supports the system in the United States. Ulvac utilizes Bruce's well established sales and service network in the United States, allowing the company to focus its energy on manufacturing and product development. Bruce, in turn receives a percentage of the sales. Ulvac gains the marketing and service credibility of Bruce International in the United States. Varian and Tokyo Electron Ltd. have a similar arrangement in the United States.

Maintenance pressures are causing equipment manufacturers to incorporate new methods for keeping the equipment operational. Equipment has become so complex that few maintenance technicians know all that is needed to properly repair it. Lam Research was the first to incorporate re-

mote diagnostics units into their systems. A Lam technician can dial up a Lam etcher, run diagnostics test and processes from off-site. Consequently, self-diagnostics and on-site support are a must.

Users seek stability in their service people. Users complain that field service technicians are often inadequately trained. One CVD equipment user complained that "one field service technician came into the fab to repair a system and could not recognize the system manufactured by his company." Such problems are compounded by heavy turnover for field service people. Service technicians often jump from one company to another for higher salaries. Thus there is a constant stream of new service persons working on a system. Companies with a stable service crew have a definite advantage. Another barrier to entry is the software compatibility. Process recipes are for the most part transferrable to the next generation equipment of the same vendor. But each vendor's proprietary software and recipes are not transferrable to a competitors system. Thus equipment users typically stay with the same vendor from generation to generation.

2.1.7 Competitive Strategies

Companies want to avoid heavy price competition and discounts at all costs. Discounts cut into a company's profitability and render it unable to invest in future product development. In order to avoid this a company will take on one of many various approaches to differentiate itself from its competition. This can be done by offering a technically superior product, selling a solution, selling cost effective hardware and offering one-stop-shopping.

One of the best strategies is to develop technically superior equipment that addresses customer needs like no other. Price wars cannot breakout when there is no other vendor who has similar technology. The early 1988 trend in CVD equipment is a typical case in point. Applied Materials and Novellus introduced multi-process systems to the market. These technically superior systems drew customers from the established vendors because they provided new solutions to problems that were barriers to new technology development by semiconductor manufacturers. Users flocked to buy the equipment at almost any price. Last-generation LPCVD furnace stacks cost $360K and had throughputs of 120 WPH. New generation, multi-process LPCVD systems cost $1000K and have throughputs of only 40 WPH--making it effectively nine times more expensive.

Established companies often strategically position themselves to 'sell a solution to customers'. AMT pioneered this strategy and it was key to their dominance of the etch market in the eighties. While everyone else offered excellent hardware, AMT guaranteed repeatable, etched wafers. In this case, the sale is made on the ability of the equipment and the ability of the vendor to provide all the process know-how necessary to process wafers. Companies that pursue this strategy will have a process engineering group as large as (if not larger than) their product development group. Selling low cost, but effective hardware is another strategy used among competitors in the equipment market. Companies fitting into this category either serve low volume niche markets or they serve high volume commodity markets. In low volume niche markets, the supplier provides a low cost alternative to costly high volume production equipment. These tools usually offer high levels of flexibility with few automation features. Prototype verification tools are good examples of this. Some companies enter a market for high volume commodity manu-

facturing by supplying low cost clone equipment. Similar to computer clones, they do all that the original does, but generally do not offer the flexibility of a general purpose system or extensive support system. Megatest pioneered this strategy with its Q8000 tester that the company introduced in the mid-seventies. It allowed them to successfully enter the logic ATE market at a time that was dominated by Fairchild.

One approach used to prevent market entry from new competitors is for companies in the market to offer equipment at minimal margins of profit. This strategy is an effective deterrent to those entering the market. In this scenario, competitors are willing to take losses in order to maintain market share. Economists call it 'contestability theory'. A prime example of this is the competitiveness that exists between Eaton and Varian in the ion implant market. These two competitors have been at each others throats since Eaton funded a start-up of former Varian employees. To this day, they fight tooth and nail over each order. They are always trying to undercut each other on price. They have even been known to offer discounts when they knew they had the order. While neither company has been highly profitable, this approach has certainly served as a meat grinder to those entering the market. ASM Ion implant ended up by selling out to Varian because of its inability to get a foothold in ion implant and because of the costly R&D expenditures necessary to compete on the technological level.

A typical strategy for conglomerate merchants is 'one stop shopping'. They offer equipment for several related areas of semiconductor production. Companies such as General Signal, Perkin-Elmer, Eaton and Teradyne have tried these approaches. Eaton failed to succeed with this strategy. It found that it was too difficult to manage all of the products. Strong products were hampered from the reputation of weak products. Additionally, weak product groups were financial drains to strong ones. While equipment buyers appreciate compatibility among equipment, they still tend to buy what is best for each individual need rather than what is the most convenient. It is essential to offer technically excellent products across the board for this strategy to work. Teradyne has been successful by insisting on technical excellence among all its product lines. Failing products are quickly cut from the product line-up.

The type of strategy taken by a company is dependent on its structure and resources. The ideal competitive market strategy will differentiate products from competitors. This avoids serious price competition. Those that fail to differentiate themselves will be forced to compete on price. Unfortunately, heavy price competition will render a company unable to invest in future products.